nine new minor planets. Three of these were found on a plate taken by Prof. Wolf on November 20, three others on a plate taken by Mr. Dugan on November 21, and the remaining three were found on a plate secured by Prof. Wolf on November 21.

ELEMENTS AND EPHEMERIS OF COMET 1902 *d*.—M. G. Fayet, of the Paris Observatory, has computed the following elements and ephemeris for the orbit of the new comet, from observations made on December 3, 5 and 8:—

T = 1903 March 13·976 M.T. Paris.

$$\left.\begin{aligned} \pi &= 119^\circ\ 52'\ 40'' \\ \Omega &= 117\ 39\ 21 \\ i &= 43\ 53\ 9 \end{aligned}\right\} 1902$$
$$\log q = 0{\cdot}45401$$

Ephemeris 12h. M.T. Paris.

1902	α (h. m. s.)	δ (° ′)	log Δ	Brightness.
Dec. 11	7 14 47	−0 39·1	0·3339	1·1
15	7 12 58	+0 4·5	0·3255	1·2
19	7 10 52	+0 52·8	0·3179	1·2
23	7 8 33	+1 45·8	0·3110	1·3
27	7 6 1	+2 43·3	0·3049	1·3
31	7 3 18	+3 45·1	0·2999	1·4

Brightness at time of discovery = 1.

An observation was made on December 10d. 13h. 37m.·0 at Heidelberg by M. Courvoisier, and gave the following position for the comet:—108° 47′ 12″, − 0° 48′ 15″, and this gives a correction to Fayet's ephemeris of −2s. and +0′·6 (*Kiel Circular*, No. 55).

"COMPANION TO 'THE OBSERVATORY,' 1903."—This annual collection of elements and ephemerides, just published, contains its usual excellent list of tables and information in regard to the astronomical phenomena which will take place during the coming year.

The information concerning the various meteor showers and double stars is supplied by Messrs. Denning and Maw respectively, and M. Loewy has again contributed advance proofs from which the variable-star ephemerides have been compiled. The latter show a considerable increase in number this year.

JUPITER AND HIS GREAT RED SPOT.

THOUGH Jupiter has been unfavourably placed for European observers during the present year, his surface markings have been extremely interesting, of great variety and in plentiful numbers. The English climate, even at its best, can scarcely be said to suit astronomical work in an eminent degree, but its characteristics in 1902 have proved unusually bad, in fact, atmospheric conditions have combined with the low position of the planet to render observations difficult, and they have generally had to be pursued with definition of very inferior quality. The seeing has been recorded as "very good" on six nights only out of seventy-five, and in 1901 the result was equally disappointing, for the image was really sharp and satisfactory on five nights only out of seventy-one; but in 1901 the planet was about 5° lower (Dec. 23° S.) than in 1902 (Dec. 18° S.), and though the difference is not great, it ought to have operated strongly in favour of the present year had other circumstances been equal.

The most noteworthy incident in connection with recent studies of Jupiter is to be found in a very pronounced acceleration of motion in the great red spot. This first made itself evident in 1901, but it has been intensified during the past summer. For about twenty-three years, uninterruptedly, this singular marking had exhibited a constantly increasing retardation, which caused its rotation period to lengthen from about 9h. 55m. 34s. to nearly 9h. 55m. 42s. But in 1901 it declined to 9h. 55m. 41s., and during the present year the rate has been about 9h. 55m. 39½s. And this increase of velocity has been contemporary with the outbreak of a large, irregular or multiple marking of a dusky hue, in the same latitude of the planet. This new object, apparently first seen in May, 1901, has shown a rotation period of 9h. 55m. 18s., which corresponds with that of the south temperate current. It seems a probable conjecture that the presence of the marking just referred to may have forced the red spot along at a more rapid rate than that which it exhibited in previous years. In June, July and August of the present year, the red spot was almost surrounded by the material of the new marking, and the quicker motion of the latter may well have accelerated the movement of the former. But no certain conclusion can be arrived at, though the facts are significant and suggestive. Possibly the phenomena alluded to may have been practically coincident in date, but devoid of any physical relationship. And in this connection it will be useful to remember that the red spot has always been situated in a stream flowing along with much greater celerity than the rate of its own motion.

In September, the material of the new marking had passed to the preceding (W.) side of the red spot, and hence it was expected that the accelerated motion of the latter would cease, but the differences in motion have been comparatively slight, so that errors of observation make it unsafe to form definite conclusions. It will be advisable when the planet disappears from the evening sky in January next to collect all the transit times of the red spot recorded during the present apparition, as it may then be possible to determine with accuracy the extent of the acceleration and the variation in its rate, if any, during the summer and autumn. If a large number of observations are forthcoming, it will be desirable to group them into monthly or bi-monthly periods and ascertain the mean longitude of the spot for each of these, when the rate of its drift will be seen and the errors of individual transits practically obliterated.

At Bristol, the following estimated transits have been obtained with a 10-inch reflector and a power of 312:—

Date. 1902.	G.M.T. h. m.	Longitude. °
April 28	16 14	45·9
May 20	14 23	44·7
June 20	14 56	44·8
,, 27	15 37	42·2
July 2	14 49	45·1
,, 7	13 54	43·9
,, 9	15 33	44·5
Aug. 8	10 8	40·2
,, 12	13 29	41·7
,, 15	10 57	42·5
,, 20	10 3	41·7
,, 25	9 7	39·6
Sept. 1	9 50	38·0
,, 13	9 48	40·3
,, 18	8 56½	40·5
,, 28	7 9	37·9
Oct. 3	6 18	37·9
,, 10	7 9	40·2
,, 15	6 13	37·1
,, 22	7 1	37·1
Nov. 8	6 8	36·9
,, 18	4 31½	39·4
,, 23	3 36	36·1
,, 25	5 20	39·1

During the present year, a number of white and dark spots have been visible on the north side of the north equatorial belt, and the mean rotation period of these has been about ten seconds less than that shown by the red spot. A new belt has lately formed on the northern side of the spots alluded to. The equatorial current of the planet has been moving, as nearly as possible, at the same rate as during 1901, for the mean rotation of twenty-four spots is about 9h. 50m. 29s. There has been an abundance of slow-moving N. and N.N. temperate markings, but these have seldom been well seen owing to the confused definition.

W. F. DENNING.

SOME LIMITS IN HEAVY ELECTRICAL ENGINEERING.[1]

IT is customary for a presidential address to be a review of the development of the science with which the Institution is particularly concerned. Such a review is especially beneficial in the case of such a rapidly growing industry as electrical engineering, as the outlook changes considerably during a year. Instead of a review of the past, a dream of the future may take the form of a presidential address. This form has great

[1] Abridged from the inaugural address by the president of the Institution of Electrical Engineers, Mr. James Swinburne.

attractions for me for several reasons. In the first place, this kind of prophecy is easy and pleasant. I might draw a rosy picture of a future when everything conceivable is done electrically. We shall have electrical energy developed direct from carbon at the coal-pits. Not only all our lighting, but all our domestic heating will be done electrically. There will be no smoke in our cities or in what will correspond to them. Most of the dirt of our houses will have vanished. Large and crowded towns will have disappeared, because the telegraph will have given way to its wireless rival, and that will have given way to the wireless telephone with no exchanges and no subscriptions. There will thus be no need for people to go and see one another to transact business. Even when matters must be written to preserve a record, no office will be necessary. You will dictate by wireless telephony to your shorthand clerk at his distant house. Perhaps we shall all learn shorthand instead of our present cumbersome system of writing, and all books and letters will be in one language, written and printed phonetically at speaking speed or faster. The horse will have gone, leaving clean and odourless streets, with smooth surfaces on which people will travel in rapid electric automobiles. The railways with very rapid long-distance service will be entirely electric. It is very easy to prophesy in this sort of way, not only in a general way, but in considerable detail; and it is an amusement that brings much credit to the prophet. If any of his prophecies seem unlikely to come true, he merely has to say, "Wait a little!" While if anything like what he foretells comes into existence, say twenty years hence, all he has to do is to refer back to an address to claim that he has foretold it, and the future inventor will have half his credit taken from him and given to the prophet. If the prophecies are sufficiently vague, there is certain to be some sort of fulfilment of some of them sooner or later, and it is always well to have a good many past publications of this sort in stock waiting for future development.

Great though the temptation is, I will resist it, and try to look into the future from quite a different point of view. We have been going ahead so very fast lately—even our acceleration itself increasing—that we may be a little apt to have vague views of what we can and what we cannot do electrically. It may be well, therefore, to try to look over some of the branches of our great and diverse industry, and see what obstacles are now opposing us and what are likely to oppose us shortly, and whether the obstacles are insuperable or not. This sort of prophecy is much more difficult than the other, for there can be no credit twenty years hence in having said something could not be done, even if it has not, while if it has been accomplished the position is still more difficult. Negative prophecy is thus unattractive. But the discussion of our limits may not only have a beneficial effect in making us modest, but it may be a much greater benefit if, by focussing our attention on a limit of any development, we find either that the obstacle is theoretically insurmountable, in which case we must go round it, or that it has to be scaled in a particular way.

There are clearly at least two kinds of obstacles. For instance, it is obviously impossible to get more than 746 watts out of a dynamo taking one horse-power to drive it. But the limit of possible speed on an electric railway belongs to quite a different category. I will therefore discuss various branches of electrical technology, to see what may prevent or is preventing further advance.

Twenty years ago, this Institution was chiefly concerned with the development of the telegraph. We can get but few telegraph papers now. This is not because telegraphy is dead; it is because most of its problems are solved, so there is little to discuss. The fact that there is little to discuss in telegraphy is the proof of its vitality. It has passed out of the childhood of technical difficulties into the manhood of commercial development. Ten years ago, we were in the thick of the evolution of the dynamo and the transformer. Now there is little but detail to discuss about electrical generating machinery. This is because heavy electrical machinery has got through its difficult infancy and is now a trade, which is the highest compliment that can be paid to it. But we electrical engineers have also developed through our difficult training into being the scientific branch of the engineering profession. Our exactness of calculation and measurement has leavened the steam engineers and the other manufacturers with whom we have to work in concert.

No one man can be a complete electrical engineer; but each of us ought to know one subject well and a large number of allied subjects fairly well. As a basis of technical knowledge, which I am alone dealing with to-night, we must have a fairly all-round knowledge of "theoretical" physics and chemistry. Physics is merely unapplied engineering. Science is split—unfortunately, the split is very difficult to heal—into two parts, generally wrongly called the theory and the practice; or pure and applied science. This fissure is not so deep in our branch of engineering, but it is there. Science, to be worthy of the name, is knowledge of Nature utilised by man. Engineering is science, and science is engineering. You can cut off a part and call it unapplied science. This is what is generally known as theory or pure science. It is not purer than any other science, and the term theory is misapplied. To be an engineer you must know both branches. There is nothing superior about knowledge which is not yet applied. It is mere raw material; it may be useful when worked up, and it is valuable before it is worked up, but only because it may be worked up. The so-called practical man who works at applications without understanding the generalised principles is ignorant. He only understands a part of science. The so-called scientific man who only understands what is called pure science is just as ignorant. Each understands part of his subject only.

We as electrical engineers ought especially to heal the split between the halves of science; a split which is much deeper in other branches of engineering, such as chemical and purely mechanical. We ought to unite knowledge of both branches of science in one individual as much as possible.

Tides.

The tides are often referred to as a possible source of energy even to this day; and it is urged that in places where the tide rises abnormally, for instance in the estuary of the Severn, it would pay to make a dam with turbines. The sort of argument is that if you have an area of, say, 1000 square metres and a total rise of 15 metres, you have 15,000 cubic metres of water, and as this runs in twice and out twice a day, you have 15,000 cubic metres of water, falling the equivalent of 60 metres a day, or approximately 100 kilowatts. This statement contains many fallacies. In the first place, in order to get the full advantage of the difference of level, the water must be let in and out at high and low tide only. Even then the equivalent or average head during discharge or charge is only $7\frac{1}{2}$ metres. But a system which gave an enormous power for a very short time four times a day would be of no use. The plant would be expensive and the result of no value. With a single tank it is impossible to get a continuous output. If the tide is coming in and you get power by letting the tide fill the tank, the power will decrease to zero as the tide begins to fall and comes to the same level as the water in the tank. It is therefore necessary to have more than one tank. To make the plant practical, you want fairly constant pressure available on the turbines, though you may waste head by sluices or valves. It is often said that a Norwegian fiord or a Scotch loch could be easily dammed and utilised, but it would be impossible to find three lochs all opening out together. The need for more than one reservoir does not seem to have been recognised. In addition, the demand for electrical energy on Scotch lochs or Norwegian fiords is rather minute.

Water Power.

Some years ago, there was a great deal of excitement about the development of water powers. The possibility of "harnessing Niagara" and utilising waterfalls all over the world was hailed as a great triumph over Nature, and the idea was that power could be got for nothing, and industries would all migrate from coal districts to the neighbourhood of water powers. The daily Press and the magazines took the matter up, and there is something in the idea of saving some of the colossal waste of natural energy that appealed especially to the half-scientific or unpractical reader. At the time of the excitement, it was pointed out, largely in vain, that water power did not cost nothing, because the development of a fall demanded a good deal of capital, on which interest and depreciation had to be paid. But further than this, Ricardo's theory of rent is applicable to water powers as well as to arable land. If steam power costs a farthing a unit, and if water power at the same place can be produced for half a farthing, after paying working expenses and interest, the owner of the water power will claim the odd half farthing as rent, or will just allow the water power enough to encourage the production of a new thing. As a rule, however, a water

power is not where it is wanted industrially. In the nature of things, water powers are generally in hilly countries, and are seldom near the sea. The result is that a water power as a rule cannot command the same price as steam or gas, because it is not where it is wanted. The idea in starting many of the water-power stations also was that works which needed power would come and settle near. As a matter of fact, the cost of power is a much smaller item in most industries than is generally supposed, and it does not pay to start a works in an otherwise not perfectly suitable locality simply for the sake of the cheap water power. In such industries as engine building, flour milling, spinning and weaving, and so on, the chance of reducing the expense for power is not enough to overcome other considerations. It may be said that in electro-metallurgical processes the whole cost is practically the electrical energy, and so carbides, aluminium, electrolytic soda and chlorate of potash will be made at water powers. Even this, however, is misleading. Carbides and aluminium are generally made at waterfalls, and chlorate nearly always is. Electrolytic soda and bleach are made at water powers, but are also made extensively by steam-driven plant. Against the cheaper power, we have to put extra carriage for materials and for coal, which is often needed in addition, and extra carriage for finished products, and very often extra cost of labour, as labour is often dear and bad in water-power districts. It may thus easily pay to use much more expensive power if the other conditions are more favourable. Steam power, for instance, will cost three or three-and-a-half times as much, and yet it pays to make electrolytic caustic and bleach in England where the other conditions are all favourable. It is not, therefore, the want of water power that has kept the electrolytic industry back in this country. For a water power to be really valuable, it should be near a source of material, on the sea, and should have a great head of water, so that the capital cost of development is small. Such a water power is very valuable—to the landlord.

A blast furnace is more valuable than a water power. There are plenty in England. But the owners, who have been wasting the gas up to now, will not give it away; they will want rent, so that it will only just pay to use this gas rather than make it. The electrical industry thus does not gain, but the ironmasters do.

Carbon Cells.

For many years, "electrical energy direct from coal" has been the dream of the electro-chemist. That is to say, he has dreamed of an electrolytic cell in which the consumed electrode is carbon. The best way to realise the difficulties of this problem is to consider it solved and see what it means. The carbon must be in contact with an electrolyte, and that electrolyte must either be in contact with a second electrolyte which wets the other electrode or must itself be in contact with that electrode. This second electrode must almost certainly be metal, as there are no other non-metallic conductors available. Such compounds as the hydrides, nitride, oxides, chloride, bromide, or the sulphide, or silicide, of carbon are not salts in the electrolytic sense. Carbon forms part of the electro-positive radicle in the organic radicles and part of the electro-negative radicle in the cyanogen compounds, but it is never a radicle by itself. To sum up the matter shortly in the light of modern theory, carbon never forms ions, and has therefore no solution pressure, and can therefore give no electromotive force. At ordinary or moderate temperatures, carbon is practically inert. Oxidising agents will attack some forms slightly, and sulphuric acid will attack it. In this latter case, the formation of water and its combination with the acid is the determining factor. At high temperatures, oxygen, sulphur, silicon, and to some extent nitrogen, and many of the metals combine with carbon, but there is no dissociable salt of carbon formed. The carbon cell thus seems impossible. Such schemes as Mr. Reed's, ingenious as it is, is not a solution of the problem. It would be simpler to reduce zinc oxide with the carbon and then put it in a zinc cell.

It is hardly necessary to discuss thermopiles or thermomagnetic engines as possible economical producers of electric power.

Steam Engines.

The primary question in all heat motors is, What temperature range is available? In the case of a steam engine, there is enormous waste of mutivity—to use a variation of Lord Kelvin's convenient term—in boiler flues. We burn carbon and hydrogen, capable even with air of giving a temperature of some 1500° C., and the heat is degraded down to some 200° C. That is to say, instead of getting the heat with a mutivity of about 0·825, we degrade it down to, say, 0·35, a clear loss of 0·45 out of 0·8, or 56 per cent. This degradation is apart from the efficiency; the efficiency is concerned with the loss of heat up the chimney. The higher limit in large modern reciprocating engines may be taken, roughly, at 600° A. (327° C. or 620° F). Above this, there is difficulty in lubrication and to some extent weakening of the material. The pressure corresponding to this temperature for saturated steam is out of the question, and the pressure may be taken at, say, 12·5 megadynes per square centimetre or 12½ atmospheres, or 200 lb. per square inch, and steam leaving the boiler superheated to 600° A. does not get at the cylinder lubrication at that temperature. Our limits in the steam engine are thus pretty clearly defined. The pressure is the essential factor. Superheating is not much good in the way of getting higher mutivity in the boiler, nor is it very important in getting much more energy into the steam.

The turbine is under the same limit as regards pressure; in fact, high pressures are perhaps even more difficult to use, and superheating does not, as already explained, seriously increase the mutivity of the heat taken in by the boiler.

One of the chief disadvantages of steam engines for stations with small load-factors is the difficulty of storing energy so as to get uniform boiler load. Batteries are no longer used for this, and the difficulty reduces the value of steam in comparison with the gas engine. Mr. Druitt Halpin has proposed, and used, "thermal storage." Lagged vessels are filled with water raised to the temperature of the working steam. This arrangement, however, is not isothermic; that is to say, to get out the energy the temperature must fall. What is wanted is a reservoir containing something which undergoes a physical or chemical isothermal change. For instance, a substance that fuses at the right temperature and has a high latent heat of fusion, or a substance which, like sulphur, changes allotropically with considerable change of internal energy, at a suitable temperature. Unfortunately, there is no substance within the range of practical engineering. Moreover, the storage is on the wrong side of the engine. To store heat with a mutivity of only some 0·35 is not so promising as to store some higher form of energy. The secondary battery thus begins with an apparent advantage. The difficulty of storage is another drawback to the steam engine, and gives the gas engine a further advantage.

The Gas Engine.

There is no other comprehensive name that covers the type of engine worked by gas and oil. The combustion need not be internal, and perhaps will not be internal in the future, but in a sense all are worked by gases.

We have in the gas engine a machine which, from a thermodynamical point of view, ought to be exceedingly good; but the difficulties in building, especially very large engines to utilise the high possible mutivity and saving by having the heat produced where used, reduce the efficiency of the gas engine enormously. In spite of that, the large gas engine seems likely to oust the steam engine for large powers during the next few years. The best way to get a high efficiency out of a gas engine would probably be to make it compound, exhausting at a temperature suitable for raising steam. The steam engine would then exhaust at a temperature suitable for raising SO_2 vapour. But the chances are that Dowson, Mond or other producer gas will be available at such low prices that the extra steam and dioxide engines would not pay for attendance, interest and depreciation. With very cheap gas, the first thing is to make big engines, the next to make them so that they never break down, and the last thing to make them efficient. The gas engine may be, comparatively speaking, in the state Watt left the steam engine, but it will doubtless make very rapid advances, as it is in the hands of very competent and highly educated engineers.

Dynamos.

As regards efficiency, we have reached the practical limit already, for further reduction in dynamo losses would make no appreciable difference in the total efficiency of a station. In fact, we are rather following continental practice in having slow-running machines with many poles, even for direct currents, and efficiencies are perhaps lower for large machines than in the best English practice of a few years ago. This is also true as regards output from a given size. We are not likely to make much advance in dynamos now, as we are limited on

one hand by the hysteresis loss in iron, which prevents our using higher inductions in armatures, and low permeability, which limits our field and armature tooth inductions. It does not seem likely that we shall now find iron much better in either respect. Nor are we likely to find a better available conductor than pure copper. As insulator we have mica. It looks, therefore, as if we were within sight of our limits in dynamo and motor designs.

Secondary Batteries.

The secondary battery in central station work has been used as a store to equalise the load, and to reduce the running plant at the times of heavy load. Owing to the high full-load station pressure with feeder systems, the station battery is generally for use at light loads only. But the secondary battery has for a long time been on the border of success for traction work, both on tramways and on the road, and a further improvement in batteries may be expected to produce very great changes in important branches of engineering.

The first question asked is, Why do we stick to lead? The answer is that the case is very special and other things will not do. We are practically limited to lead, at any rate in acid cells. Take first the plate that oxidises on discharge. It should not dissolve in the electrolyte, as if it does the deposition and solution will be uneven, and the plate will grow trees and come to grief. This puts zinc out of court, unless some electrolyte is used which gives some insoluble salt of zinc, which does not attack zinc on open circuit, and gives a good electromotive force with it. Iron is out of court for the same reason; there is no suitable electrolyte. The strong organic acids such as trichloracetic or oxalic are apt to have their positive radicles split up by electrolysis, even if a strongly positive metal can be found with an insoluble salt. Lead is thus the only metal practically available in an acid electrolyte. Silver in hydrochloric acid would give no pressure, and the acid would be decomposed at the anode. On the other plate we need an insoluble depolariser, else a two-fluid cell must be used, involving a porous diaphragm, diffusion and impracticability. Not only must the depolariser be insoluble, but it must be converted into an insoluble body on discharge. The coating must be a conductor in one state or the other, or there will be no proper contact. In the lead cell, there is always enough peroxide and metallic lead in the coatings to secure electrical contact though the discharge product is an insulator. The depolarising coating must be connected to a conducting plate which is not attacked by local action. Lead and silver are the only available metals, and sulphuric, and perhaps phosphoric, the only acids, for the nitrate of lead is soluble and hydrochloric acid is decomposed by lead peroxide. Lead is protected by its coating of sulphate, or peroxide as the case may be. It thus seems as if we were limited almost absolutely to lead and sulphuric acid. It is wonderful that we have the lead cell at all. We owe it to the chance observation of Planté. The theory was not understood for a long time. For many years it was thought that the pressure was due to the PbO_2 and Pb changing into PbO. The acid was merely put in to make the electrolyte conduct, and sulphuric acid was used because people used it in gas voltameters, and they never thought that it ought to be as strong as practicable to give the pressure and output. The formation of lead sulphate was regarded as a difficulty to be overcome.

In the lead cell we want lightness, large capacity, cheapness, rapid discharge, efficiency and mechanical strength, and durability. These qualities are mostly antagonistic. Large capacity means rapid deterioration. Mechanical strength means weight. It is thus no use testing a cell for capacity without testing the efficiency and durability too, and so on. Published battery reports are often misleading, because they omit essential information.

Cables.

The conductor itself can hardly be improved, but there is great room for improvement in the insulation. It is largely the insulation of the cables that limits our pressures, and therefore our distances of transmission. For 1000 kilowatt cables, the cost is about a minimum for 8000 volts; above that, the cost of insulation increases faster than the cost of copper falls. It is exceedingly unlikely we have reached the limit in insulation. There is no branch of electrical engineering so important as cable making. Cables form a large portion of the capital outlay in large systems. Yet there is no branch of the industry which is run on less scientific lines. The days of secret mixtures known only to the workman who makes them may be passing away; but even now the whole art of cable-making is a question of trial and error, with a good deal of the last component. Engineers do not know now whether rubber is better than paper, nor can they tell what any particular make of cable will be like after ten years' use.

Light.

Our chief work, until lately, has been producing light. Here the inefficiency and waste is prodigious, and though it is mostly unavoidable, there is still great room for improvement. We take great care over our stations, watching every penny from the coal shovel or mechanical stoker to the station meter. We quarrel over 1 per cent. in the generators. When we get to the mains we care less, and once we have got to the consumers' meters we care nothing at all.

Practically all light is wanted for use by the human eye. The human eye is exceedingly sensitive; it is calculated to see a distant star when receiving 10^{-8} ergs per second, so that one watt would enable, say, five thousand billion people to see stars with both eyes, but it would have to be used economically. In reading a book, the eye would need much more than this; and then, as the book radiates light in half of all directions, only a little is used by the eye, so even if all the light from a source were concentrated on a book, there is enormous waste by useless radiation from the book. But the source of light does not illuminate only the book; the book probably subtends a small solid angle, so we have another source of waste. The eyes reading a book in a fairly good light want something of the order of two ergs per second, so that a watt would only work the optic nerves of, say, the inhabitants of London. But the book, say 200 square centimetres, would need about 3000 ergs a second to illuminate it. A candle, which gives a light of 4π, radiates about 0·2 watt, or five candles a watt; that is to say, at an efficiency of unity, we would get five candle-power or 20 units of light per watt. The efficiency of a glow-lamp is only about 0·25 candle-power per watt, or 0·05, so there is room for improvement. The first thing, naturally, is to see what limits there are in the way of increased efficiency. The obvious goal is direct production of "light without heat," by which is meant producing only the rays of wave-lengths which affect the eye.

There is no thermodynamical reason why electrical energy should not be converted directly into radiation of any wave-length without loss; I do not know if there is any molecular impossibility, but apparently our limits are practical—that is to say, it may be done, but we have not yet hit on the way of doing it. The vacuum tube appears to be a means of converting electric power direct into radiation. The Cooper-Hewitt lamp, for instance, gives an efficiency of about three candles per watt, or something like 0·6. All these figures as to light are a little vague. Unfortunately, the light is of a very bad colour. It is very actinic, but the wave-lengths are too small. One method is to degrade the light by making it act on silk dyed with matters which lower the radiation to a redder colour by fluorescence.

The Arc Light.

The arc has been very fully studied in some directions and not in others. Most makers of arc lamps seem to devote their whole attention to the mechanism, and look upon the arc merely as a hot gap that has to be preserved by suitable apparatus. Many lamp makers, on the other hand, have records of exhaustive experiments on the relations of the pressure, current and light with different carbons; but they are very seldom published. On the other hand, an enormous amount of laborious experiment on such points as these is available, and on the back electromotive force of the arc. The physics of the arc, an exceedingly difficult branch of study, has not received much systematic attention yet. The crater of an arc is, no doubt, heated to the point of volatilisation of carbon at the pressure of the air. If other gases get at the crater, the vaporisation temperature would be less. (There is a small increase of pressure which I suggest is due to the electromagnetic effect of a current localised in a conducting fluid. This may be neglected.) The crater may be rough, as carbon, though it softens, does not melt before volatilising, and it may be merely speckled with points at its volatilising temperature, so that its brightness is not uniform. But there are so many anomalies about the arc that one cannot say anything definite with safety. For instance, if the temperature is limited by the vaporisation of carbon, what must be the specific heat of vaporisation of carbon? Where does the vapour go, and what happens to it in an enclosed lamp? In condensing into smoke, it should give light of the

same colour as the crater. If it has an enormous specific heat, it ought to raise the other pole to crater temperature where it condenses. If it is a light gas, a large portion of its specific heat of vaporisation may go to external work. Most of the upper carbon is burnt away by external air; if a pencil to match the crater is volatilised, it does not account for much power. If the vapour is very light, there must be large volumes from the upper carbon. Then what conducts? Carbon vapour alone, or mixed with a little monoxide or nitrogen, is a very good conductor at these temperatures. Does that go to show that carbon vapour dissociates like iodine or chlorine, &c.? The whole question of the physics of the arc deserves far more careful study than it has yet received, but the work is surrounded with difficulties and is really a branch of the theory of the passage of electricity through gases, a matter of the greatest scientific importance, somewhat out of our way as practical electrical engineers. But as engineers in the broader sense, we are as much interested in questions of recondite physics as of costs of generation.

To sum up as to the arc light, we do not seem to have reached our limit as to light from pure heating, because we lose a lot of light into the opposite carbon. Many attempts have been made to expose the crater freely. But, far more important than this, I would urge that the arc is not necessarily a hot body radiator only, but that it may also convert electrical power directly into light in the space between the electrodes, and this gives a chance of rising more nearly to our theoretical limit of about five candles per watt.

The Incandescent Lamp.

This simple hot carbon wire in a bulb involves the most extraordinary physical complexities. A great many curious things go on inside the simple-looking globe. A good account of what is known—especially since he took the subject in hand—has been written by Dr. Fleming, and the scientific manufacture of this interesting article has been fully described by Mr. Ram. The incandescent lamp is a simple hot body radiator, and the limit of efficiency depends chiefly on the temperature of the carbon. As we are limited by the size of mains, we can only use pressures of 100 volts or 200 volts, and this limits us to carbon or something of still higher specific resistance. The sensitiveness of the carbon lamp to pressure in its turn limits the practical variation of pressure of supply, and thus costs us very heavily in mains. If we had incandescent lamps which did not mind 20 per cent. pressure variation, we would have saved millions in mains in this country alone.

The idea of making lamps of carbides has become very fashionable lately. People have put oxides into carbon for the last twenty years. The old idea is to get hold of an oxide that radiates more light at a given temperature than it ought to, which is itself a fallacy, while the idea of oxide in contact with carbon is chemically absurd. There is no oxide irreducible by hot carbon. The carbides are not by any means all refractory. Some are, though, but there are immense difficulties in making carbide lamps. To make a fine filament material of an infusible material, which can be made only at electric furnace temperatures and is generally decomposed by moist air, is not an easy task. It is easy to think you have made a carbide lamp by incorporating an oxide in the filament material, but the resulting filament is generally mostly, if not wholly, carbon. What happens to the metal in the circumstances is rather a mystery. There is, however, a chance of enlarging our limits in incandescent lamps of the ordinary kind, but it seems strange that the melting points of all known materials should suddenly reach a higher limit. Assuming the Stefan-Boltzmann law for ordinary light radiations, the fact that the efficiencies of refractory bodies all reach limits of the same order shows that the most refractory bodies melt at about the same temperature, somewhere in the neighbourhood of 3000° A. Whatever the inter-molecular forces may be that bind the particles to make solids, the vibration forces due to temperature seem to overcome the greatest at about 3000°.

Instead of an ordinary conductor, Nernst uses an electrolyte which stands a higher temperature. The conduction is electrolytic, as can easily be shown, but there are many curious phenomena, many of them so far unexplained, in the Nernst lamp. The efficiency of the Nernst lamp is about 0·6 candle per watt. It was at one time supposed to owe its efficiency to selective emission, but there is no reason to doubt that it is a pure temperature radiation.

Electric Heating.

The limit of electric heating is clearly purely financial. To convert heat into other energy with a very small efficiency and to send it out by expensive cables and then to degrade the energy down to heat again is obviously much dearer than burning coal or gas direct. But in many domestic cases, the convenience is so great that the limit is not so low as might be thought, and electric heating for cooking and other domestic uses may develop considerably. The electric arc and incandescent lamps are essentially cases of electric heating. By far the most important use of electric heating is the furnace. Here the temperature available is only limited by the volatilisation of the electrodes, and this enables us to get temperatures otherwise unavailable, so that we can get chemical actions which are impossible at lower temperatures, either because they are endothermic or because the materials do not come into chemical contact at ordinary temperatures. It is impossible to say what our limits are in the electrical furnace. Probably the temperature is limited by the volatilising of carbon. The products are not limited to endothermic compounds; the furnace is useful for the reduction of metals and phosphorus, and for melting glass and, it is hoped, silica for optical and laboratory purposes, and perhaps for cooking utensils and evaporating pans and crucibles in chemical engineering and metallurgy.

Railways.

It is almost absurd to begin to consider the limits of the use of electrical transmission on railways at this date. The future of electric railways, electric tramways and automobiles is rather a matter of vague conjecture and picturesque prophecy. Tubes are multiplying rapidly, and railways are putting down electric transmission on suburban lines in Europe and the States. On short lines with many stops, we have to contend with inefficiency at starting. On long lines, there is difficulty of transmission or cost of transformation and difficulties of collection. We are limited by the want of either a variable speed simple alternate-current motor or a simple variable speed-gear capable of transmitting a very large torque and packing into an engine. A recently developed scheme is the use of low-frequency alternating currents with laminated series-wound motors. This solves the difficulty, but at the expense of large idle current, induced pressure in short-circuited armature coils, large expensive and inefficient transformers, and the ordinary disadvantages of the series-motor on constant pressure. This plan is well worth serious study.

The collection of large currents at great speeds has long loomed as a limit. The published accounts of experiments at Zossen would lead us to suppose there is no trouble on this score. Still, it is a difficulty many engineers fear.

In electric tramways, there is no limit in sight. The power can be sent over any distance desired, and there seems to be no limit to the people who want to travel on electrical trams. The question of electrolysis is rather that of a limit to the duration of pipe companies' property. It is a very difficult question. Though the threatened effects of electrolysis have no doubt been exaggerated, it is at best a question of degree, and the ingenuity of engineers is continually reducing the chance of damage. It has recently been urged that frequent reversals of polarity of the system reduce the electrolysis very considerably.

Electrolysis.

This is a branch of industry in which it is very difficult to tell our limits. In electrolytic copper-refining, our limit is that of the copper wanted. Our electrolytic industries suffer mostly from the limits of intelligence of the investing public. It is assumed that we cannot do electrolysis in England because we have no water power. This is only an excuse for inactivity. As already explained, we can do just as well without water power. A blast furnace is much more valuable than a waterfall of similar power, because it is near coal and in an industrial district. Moreover, as already explained, the cost of electrical energy is a small portion of that of most electrolytic products. At first, electrolysis was to be applied to copper-refining. Then to caustic soda. The output of electrolytic caustic is really rather limited by the demand for bleach. What is urgently wanted is some other way of storing and carrying chlorine. Steel bottles and compression plant are an unsatisfactory solution. What are the limits in the way of electrolysing fused salt They are all incidental limits. The containing vessel is

difficulty. Sodium vapour attacks all silicates. Sodium distils near the temperature of fused salt. If not volatilised, it forms a conducting bridge from the kathode. It attacks iron, though slowly. Hot porcelain and earthenware conduct electrolytically —as, by the way, the maker of electric frying-pans knows—hot chlorine attacks metals, even when dry, and hot carbon cannot be exposed to the air. In addition, sodium and perhaps chlorine are soluble in hot salt, and traces of sulphate in the salt act as carriers. I could a tale unfold if I read out laboratory notes of sodium experiments on a fairly large scale. The difficulties are all incidental, though, and I have little doubt electrolytic sodium at a few pounds per ton will be in the market soon, and will affect profoundly many chemical and metallurgical industries.

In metallurgy, electrolytic solution processes are in use or on trial for the more valuable metals, such as copper and nickel. The reaction between chlorine and metallic sulphides at high temperatures brings the whole domain of sulphide ores under our sway. Thus a sulphide, say galena, is treated with chlorine, which gives off the sulphur as sulphur, which is condensed and sold, making chloride of lead. The silver is extracted by stirring with a little lead, and the fused salt is then electrolysed, yielding pure desilverised lead and chlorine. The process is thus self-contained, yielding sulphur, lead and silver. It is specially applicable to mixed refractory ores which are now nearly valueless and very plentiful, and contain much metal content, such as the mixed lead-zinc sulphides of America or Australia. These reactions have been proved on the large or ton scale, and there is no technical difficulty. Unfortunately, mine people are somewhat ignorant of electrical matters, and it is exceedingly difficult to get them to understand or appreciate a process like this, capable though it may be of paying good dividends on very large capitals indeed.

Our limit in electrolysis in this country is almost entirely human inertia. Commercial and financial people do not understand it, and fight shy of it. But our technical people are nearly as bad. The pure physicist, as a rule, takes no interest in electrolysis or physical chemistry, and thinks it belongs to the chemical classroom on the other side of the passage. The chemist thinks it is higher mathematics and will have none of it, the mathematician thinks it may be an exercise in differential equations; but they are all agreed that it is a sort of continental fungus which flourishes with no roots, and that it is beneath the attention of a scientific man to know enough about it to give a reason for the broad statement that it is all nonsense.

DUTY-FREE ALCOHOL FOR SCIENTIFIC PURPOSES.

TEACHERS of organic chemistry have often expressed the opinion that alcohol used for purposes of education and research should be relieved of the heavy duty levied upon it. Two years ago, attention was directed to the need for action in the matter, and at the Glasgow meeting of the British Association in 1901, a committee was appointed, with instructions to approach the Board of Inland Revenue, with the object of endeavouring to secure the removal of this tax upon scientific work. As the result, the following regulations have been issued by the Board and published in the daily Press:—

Regulations for the Use of Duty-free Spirit at Universities, Colleges, &c.

(1) An application must be made by the governing body or their representatives, stating the situation of the particular university, college, or public institution for research or teaching, the number of the laboratories therein, the purpose or purposes to which the spirits are to be applied, the bulk qnantity likely to be required in the course of a year, and, if it amounts to fifty gallons or upwards, the name or names of one or more sureties, or a guarantee society to join in a bond that the spirits will be used solely for the purpose requested and at the place specified.

(2) The spirits received at any one institution must only be used in the laboratories of that institution, and must not be distributed for use in the laboratories of any other institution, or used for any other purpose than those authorised.

(3) Only plain British spirits or unsweetened foreign spirits of not less strength than 50 degrees over proof (*i.e.* containing not less than 80 per cent. by weight of absolute alcohol) may be received duty free, and the differential duty must be paid on the foreign spirits.

(4) The spirits must be received under bond either from a distillery or from an Excise or Customs general warehouse and (except with special permission) in quantities of not less than nine bulk gallons at a time. They will be obtainable only on presentation of a requisition signed by the proper supervisor.

(5) On the arrival of the spirits at the institution, the proper Revenue officer should be informed, and the vessels, casks or packages containing them are not to be opened until he has taken an account of the spirits.

(6) The stock of spirits in each institution must be kept under lock in a special compartment under the control of a professor or some responsible officer of the university, college or institution.

(7) The spirits received by the responsible officer of the institution may be distributed by him undiluted to any of the laboratories on the same premises.

(8) No distribution of spirits may be made from the receiving laboratory to other laboratories which are not within the same premises.

(9) A stock book must be provided and kept at the receiving laboratory in which is to be entered on the debit side an account of the bulk and proof gallons of spirits received with the date of receipt, and on the credit side an account of the bulk and proof gallons distributed to other laboratories. A stock book must also be kept at each other laboratory, in which must be entered on the day of receipt an account of the bulk and proof gallons of spirits received from the receiving laboratory.

These books must be open at all times to the inspection of the Revenue officer, and he will be at liberty to make any extract from them which he may consider necessary.

(10) The quantity of spirits in stock at any one time must not exceed half the estimated quantity required in a year where that quantity amounts to twenty gallons or upwards.

(11) Any contravention of the regulations may involve the withdrawal of the Board's authority to use duty-free spirits.

(12) It must be understood that the Board of Inland Revenue reserve to themselves full discretion to withhold permission for the use of duty-free spirit in any case in which the circumstances may not seem to them to be such as to warrant the grant of it.

J. B. MEERS,
Secretary.

Inland Revenue, Somerset House, W.C., November 17.

NOTE.—"Proof Spirit" is defined by law to be such spirit as at the temperature of 51° Fahrenheit shall weigh $\frac{12}{13}$ths of an equal measure of distilled water.

Taking water at 51° Fahrenheit as unity, the specific gravity of "proof spirit" at 51° Fahrenheit is 0·92308. When such spirit is raised to the more usual temperature of 60° Fahrenheit, the specific gravity is 0·91984.

To calculate the quantity of spirits at proof in a given quantity of spirit over or under proof strength:—Multiply the quantity of spirit by the number of degrees of strength of the spirit, and divide the product by 100. The number of degrees of strength of any spirit is 100 *plus* the number of degrees overproof, or *minus* the number of degrees underproof.

EXAMPLE:—19·8 gallons of spirits at 64·5 overproof
$100 + 64{\cdot}5 = 164{\cdot}5$ proof strength.
$164{\cdot}5 \times 19{\cdot}8 \div 100 = 32{\cdot}571$
taken as 32·5 gallons at proof.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—In connection with the School of Geography, Mr. Mackinder will lecture weekly during Hilary term on the historical geography of Europe, Mr. Dickson will lecture on surveying and mapping and on the climatic regions of the globe; he will also give, in conjunction with Mr. Darbishire, practical instruction in military topography; Mr. Herbertson will lecture on the British Isles, the regional geography of continental Europe, and on types of land forms, mountains and coasts; Dr. Grundy will lecture on the historical topography of Greece, and Mr. Beazley on the period of the great discoveries, 1480–1650.

SIR WILLIAM COLLINS has accepted the invitation to stand as the Liberal candidate for London University at the ensuing Parliamentary by-election.